National Aeronautics and Space Administration

INSTRUMENTATION FOR THE HIGH ICE WATER CONTENT (HIWC) FLIGHT CAMPAIGNS

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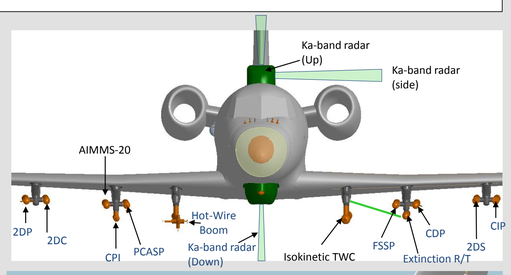
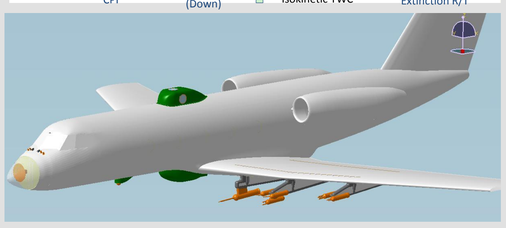
Objective

- To Identify, Develop/Modify, and Qualify Cloud Physics Instrumentation for High Ice Water Content Characterization Flight Campaigns



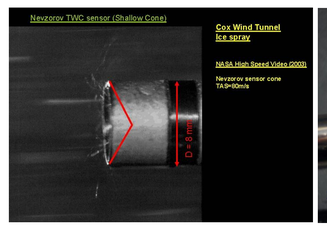


Measurement Type	Instruments/Probes
Water Content	NRC Isokinetic TWC Evaporator, Hot-wire boom with SEA "robust" probe, Nevzorov LWC/TWC probe, SEA LWC probe, King LWC probe Note: red font indicates new or modified for HIWC
Cloud Spectrometers	PMS Forward Scattering Spectrometry Probe, DMT Cloud Droplet Probe, SPEC 2D-S, SPEC Cloud Particle Imager, PMS Optical Array Probe 2D-C, DMT Cloud Imaging Probe, PMS Optical Array Probe 2D-P
Atmospheric State	AIMMS-20 wind/gust probe, Goodrich total air temperature (TAT), UK Solid Wire TAT, LICOR water vapor, Buck Research CR-2 hygrometer, Edgetech Model 137 hygrometer, MayComm TDL open path hygrometer
Light Extinction	EC Cloud Extinction Probe
Ice Detection	Goodrich 0871LM5 ice detector, Goodrich 0871FA ice detector,
Remote Sensing	Honeywell RDR-4000 pilot weather radar, Ka-band cloud profiling radar, L3Com WX-500 Stormscope
Imaging & Audio	High Def and Standard Def cameras, video annotator, HD and SD recording decks to capture windscreen, research instruments, engine inlets
Aerosols	TSI Condensation Nuclei (CN) counters, Scanning Mobility Particle Sizer
Aircraft & Engine Data	Airspeed, altitude, position, heading, roll, pitch angle, vertical acceleration, engine N1, N2, TGT, throttle position

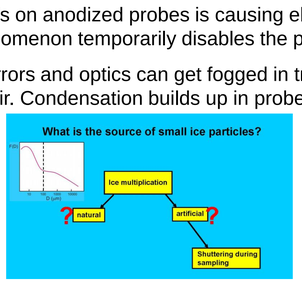
Technical Challenges

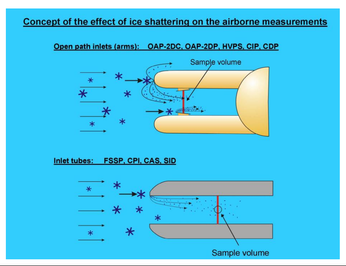
HIWC conditions present several technical challenges for cloud physics instruments

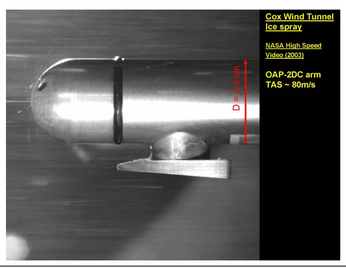
- Water Content Measurement:
  - Issues:
    - **Saturation:** legacy hot-wire probes saturate at 1-2 g/m^3 at 200 m/s. HIWC can theoretically reach 9 g/m^3.
    - **Under-sampling:** ice and liquid water can bounce, break up and shed from legacy hot-wire probes before fully evaporating, causing measurement to be low
    - **Damage:** Ice impacts on legacy hot-wire probes can deform, erode and break the wires
  - Challenge: Develop water content probes:
    - To measure up to 10 g/m^3 at 200 m/s
    - Do not under-sample due to mass loss
    - Robust to the damaging HIWC environment

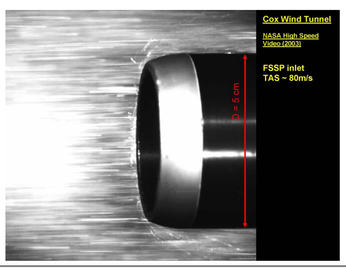


- Particle Spectra Measurement:
  - Issues:
    - **Artifacts:** In some types of glaciated conditions, legacy and SOA spectrometers are over estimating concentrations of small ice particles due to the impact of larger particles on probe tips and inlets and resulting breakup into small fragments
    - **Electro-static Discharge:** high speed impacts of ice crystals on anodized probes is causing electro-static charge to build up and discharge through the probe ground. This phenomenon temporarily disables the probe electronics.
    - **Optics Obscured/Condensation**: Spectrometer probes mirrors and optics can get fogged in tropical air after cold soaking at high altitude and descending into high humidity air. Condensation builds up in probe canister.
  - Challenge: Develop mitigations to:
    - the reduce ice particle artifacts,
    - electro-static buildup
    - optics fogging/condensation build-up



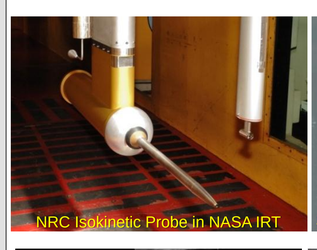






Technical Approach: Design, Build, Test

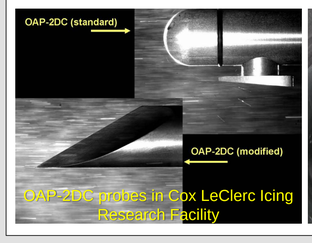
- To address Water Content Measurement challenges:
  - NRC developed an Isokinetic Evaporator Probe to measure Total Water Content to 10 g/m^3 at 200 m/s
  - SEA developed a "robust" total water content hot-wire probe to withstand damaging ice impacts
  - EC developed new sensor vanes for Nevzorov LWC/TWC to reduce mass loss / under-sampling
  - New hot-wire boom with new sensors designed for HIWC research aircraft
- To address Particle Spectra Measurement challenges:
  - EC developed new tips and arms for the FSSP, OAP-2D2C, DMT CDP and CIP, SPEC CPI
  - EC/NRC/NASA identified titanium nitrite (TiN) coating on probes to manage electro-static buildup
  - Dry air purge system defined to keep optics clear; manage condensation within probes
- Wind Tunnel Tests and Flight Tests Conducted to Verify/Qualify Instrument Readiness
  - Multiple entries at NRC M-7, NASA IRT, and Cox Icing Tunnel; NRC Convair 580


NRC Isokinetic Probe in NASA IRT


SEA "Robust " TWC probe in NASA IRT

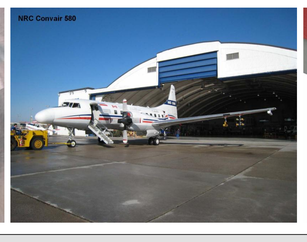

FSSP in NRC M-7 Test Cell

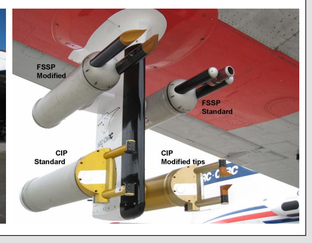

OAP-2DP in NRC M-7 Test Cell



OAP-2DC probes in Cox LeClerc Icing Research Facility


AIMMS-20 Probe with new TiN coating in NRC M-7 Test Cell

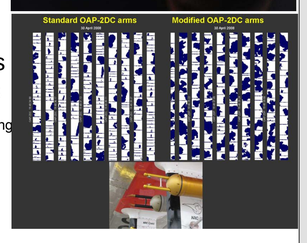




Results:

- NRC Isokinetic Evaporator Probe:
  - Successfully tested to 9 g/m^3 of ice water content; inlet tip icing issue identified and remedied; new controller developed and successfully tested; probe undergoing upgrades for airworthiness.
  - Davison, C. R., MacLeod, J. D., and Ratvasky, T. P., "Naturally Aspirating Isokinetic Total Water Content Probe: Preliminary Test Results and Design Modifications", 2010, AIAA-2010-7530, 2nd AIAA Atmospheric and Space Environments Conference, Aug. 5, 2010, Toronto, ON, Canada, AIAA.
- SEA Robust Probe:
  - Used for 3 winters at NRC M-7 for TWC mapping without failure;
  - used on Airbus A-340 flight test for HIWC

- New Spectrometer Probe Tips Reduce Ice Particle Artifacts
  - Wind tunnel test and CV-580 test confirmed new tips reduce particle artifacts in measurement area; improve spectra measurement in glaciated conditions
  - Korolev A. V., E. F. Emery, J.W. Strapp, et al, "Small Ice Particle Observations in Tropospheric Clouds: Fact or Artifact? Airborne Icing Evaluation Experiment", Bulletin of the American Meteorological Society, 2010



- TiN Coating Fixes Electro-Static Issues:
  - AIMMS-20 test in NRC M-7 tunnel confirmed no-lockup in HIWC conditions
  - TiN coating now being applied to other electro-static sensitive instruments

Conclusions:

- Through collaborations between NASA, the FAA, Environment Canada, National Research Council of Canada, and SEA, issues of operating cloud physics probes in an HIWC environment were identified and remedies were designed, fabricated, and tested.
- As a result, new and improved instruments will be integrated on the HIWC Research Aircraft and flown in the upcoming trial and primary flight campaigns in Darwin, Australia.
- This assures that the highest-possible quality measurements will be made for this important field campaign. The data set will be used for decades to come.

Environment Canada

NRC CNRC Aerospace

SEA SCIENCE ENGINEERING ASSOCIATES, INC.

Federal Aviation Administration